GEOPHYSICS

Project title: Absolute Gravity and Crustal Deformation in the Yellowstone Caldera

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Objective: The determination of temporal changes in gravity is important for assessing mass/density changes of volcanic calderas. Mass density changes reflect magmatic and/or hydrothermal activity and are an indicator of likelihood for eruption. We are collecting repeat absolute gravity and ancillary global positioning satellite (GPS) measurements in Yellowstone National Park to monitor the changes in gravity with respect to vertical height (free-air gravity change) of the Yellowstone Caldera.

Mass/density and vertical height changes reflect the movement of water and inflation/deflation of geysers and geyser basins. We are collecting temporal gravity and GPS datasets at individual geysers and plan to extend this to several geyser basins to address geyser dynamics.

Findings: We have acquired new data that indicates there are large temporal microgravity and ground motion signals associated with Yellowstone geysers. In October 2001 we observed a 8–10 microgal quasi diurnal signal in absolute gravity at the East Warming Hut in the Old Faithful Village at a distance of 70 meters from the Old Faithful geyser. This amount of gravity change is equivalent to 3–5 centimeters of vertical motion if there were no mass changes. We observed centimeter level variations in the ground motion at the same site with GPS data. Preliminary comparisons of observed gravity and ground motion suggest that the vertical motions are accompanied by mass changes. These observations are significant to characterizing geyser dynamics and require further data acquisition to quantify the mass motion and deformation of Yellowstone geysers and geyser basins.

In October 2001 we also revisited our baseline absolute gravity site at Canyon Village and established a new baseline site at Mammoth. We were able to complete some of the gravity gradients at our other baseline sites that we need to compare our 2000 absolute gravity measurements with previous relative gravity observations. We are planning to revisit all of our baseline sites in 2002 as well as make observations at some additional geyser basins.

Project title: Crustal Structure and Composition of Yellowstone National Park: Relation of

Crustal Structures to Geology, Hydrothermal Alteration, and Seismic Activity

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Objective: A high-resolution aeromagnetic survey flown over Yellowstone National Park shows a broad spectrum of contrasting magnetic patterns reflecting variations in rock composition, types and degree of alteration, and crustal structures. Compared with previously obtained low-resolution aeromagnetic data, which showed broad regional geologic trends, the new aeromagnetic data collected at low-altitudes with closely-spaced flight lines and integrated with geologic mapping, rock property measurements, and remote sensing data show this high-resolution data to be extremely useful in revealing small-scale geologic features. This method has identified fractures and areas of alteration that previously have not been mapped, identified the extent of individual geologic units and structures, and estimated the magnitude of hydrothermal alteration. Magnetic gradient trends follow the mapped north-south Basin and Range structural trends. These trends are at small scales such as in the hydrothermal basins and at larger scales such as with fault systems suggesting that the regional stress field localizes much of the present-day hydrothermal activity.

Objectives in this final phase will include a focus on collecting samples for rock magnetic and other physical characteristics to refine interpretation of aeromagnetic data; examination of the interrelationship of hydrothermally altered rock units, slumping soils on steep terrains, and timing of deformation; and investigation into the interrelationship of structural trends, fossil and active hydrothermal alteration, and regional seismicity.

Continue analysis of new high-resolution aeromagnetic survey over most of YNP and compare with magnetic susceptibility and remanence measurements. Collect and analyze magnetic remanence and susceptibilities of fresh and altered volcanic and sedimentary rocks. Prepare manuscripts of aeromagnetic data in terms of its usefulness in mapping volcanic flows, faults, and zones of alteration. Compare magnetic susceptibility, zones of alteration, oxygen isotopes, and total magnetic intensity of specific volcanic units. Demonstrate flow directions of ignimbrites in the Yellowstone Plateau volcanic field using anisotropic magnetic susceptibility.

Visual inspection of the aeromagnetic map with superposed geologic features suggests that there may be distinctive magnetic anomaly minima associated with mapped zones of hydrothermal alteration of the source rocks. To investigate this, we want to accomplish three objectives: 1) Quantify and verify the relationship between the lows and alteration and use the aeromagnetic data to map the extent of alteration zones beneath covered areas. 2) Analyze the aeromagnetic map for trends, which might delineate the structural fabric of older geologic structures which controlled the loci of volcanism within the Yellowstone system. 3) Map textural measures of the aeromagnetic anomaly field, which might be related to rock lithologies and thus be of use in elucidating the geologic structure. To do this, we will apply new analysis tools in conjunction with Mark Gettings (USGS,

Tucson) to the data and field check the data.

Findings: A paper describing the method and the case study will be published.

Project title: Operation and Development of an Earthquake and Volcano Information System At Yellowstone (YSGN) and Ancillary Research on the Geodynamics of the Yellowstone Hotspot

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Objective: The Yellowstone seismic and GPS networks (YSGN) operates an earthquake and GPS information system at Yellowstone National Park and surrounding area focusing on the Yellowstone volcanic field and associated fault zones. Specific tasks include operation of the 22-station seismic and five-station GPS (Global Positioning System) network station installation, maintenance, recording, processing, and analyses of data from these systems. The primary goals of the YSGN are to monitor and assess seismicity and ground deformation that may be related to both volcanic and earthquake activity. Data are provided to the National Park Service and USGS management, NPS public safety and interpretation groups, as well providing online data for scientific research for interested users.

Findings: In this report period we expanded our efforts to establish the USGS Yellowstone Volcano Observatory (YVO), a joint partnership between the USGS, the NPS and the University of Utah that provides a coordinated planning and implementation body. The USGS Volcano Hazards Program jointly funds this cooperative project with partial support form the National Park Service (NPS) for field work. The National Science Foundation provided funds for three of the GPS stations. The primary products of the project are earthquake catalogs, ground deformation information, and the services of a regional earthquake and GPS recording and information center, including timely release of unusual volcanic and earthquake activity reports to the USGS and the NPS.

The YSGN is designed to monitor earthquakes by seismic and GPS methods of the Yellowstone volcanic system, including Yellowstone National Park and the nearby Hebgen Lake fault zone. This project provides real-time earthquake surveillance by an upgraded 22-station, 32-component, seismic network telemetered to Salt Lake City, Utah that is digitally recorded at the University of Utah. Five continuously recording GPS stations provide monitoring of the crustal deformation that is focused on the caldera and related features.

Special note: Backcountry access for fieldwork in Yellowstone was curtailed due to FAA grounding of the NPS contracted helicopter following the September 11 terrorist attack. This resulted in postponement of much of our planned fieldwork for 2001 until summer 2002.

In addition to routine network operations, notable efforts under this cooperative agreement during the report period related to fieldwork as follows: Continued upgrading of seismograph stations against the harsh winter conditions of Yellowstone. This included 1) seismic and GPS instrument repairs and upgrades, 2) replacement of batteries at numerous sites, 3) repair of ice damage to radio antennas, solar panels, and cables, and 4) installation of a new digital seismic station at Old Faithful. This was done at several seismic and GPS stations and telemetry relay stations.

Assistance to the National Park Service with long-term plans for implementing volcano and earthquake hazard assessment and identifying manpower needs and preparing for data input into the new science centers at Old Faithful and Canyon and tuning up the helicorder in the Old Faithful Visitors Center.

A major effort this year was the organization of the Yellowstone Volcano Observatory (YVO). Meetings were held in Yellowstone National Park with USGS, NPS and University of Utah representatives to plan the organization and to facilitate communication between these groups. An MOU between these groups was signed in June 2001 that formalized the YVO and a web site was established for status of volcano and earthquake information, monitoring status and related information. Monthly updates of monitoring activities are posted to the YVO site at: http://volcanoes.usgs.gov/yvo.

Epicenters of 1,900 earthquakes (M_? 3.8) were located in the Yellowstone region during the period October 1, 2000 to September 30, 2001. The seismicity sample includes two shocks of magnitude 3.0 or greater and no shocks of magnitude 4.0 or greater. The largest earthquake within the Yellowstone region during the report period was a shock of magnitude 3.8 that occurred on November 24, 2000 (04:20 UTC), located two miles north of Norris Junction, WY.

GPS field campaigns, at up to 140 points in and around the Yellowstone hotspot, were conducted in 1995 and 2000 to measure deformation of the Yellowstone volcanic system. The 2000 campaign also incorporated data from continuous GPS stations in Yellowstone and the eastern Snake River Plain. Station positions from each year were combined to obtain the station velocities for the network. In order to constrain the network to a North America fixed reference frames, coordinates of easternmost stations were fixed. These stations were assumed to be in the stable continental interior.

For the Yellowstone caldera, GPS results revealed uplift, with up to 8 mm/yr, north of the caldera and horizontal southwest extension of 6 mm/yr. The uplift represents a reversal in the direction of vertical deformation from the earlier decade, 1985 to 1995.

The University of Utah personnel published ten papers using data from the Yellowstone Seismic and GPS Network.